THE MINING WHEEL

Gregory Abramov
Borehole Mining International, Inc.

ABSTRACT

The 20th Century Industrial progress kicked-off development of such sophisticated mining technologies as in-situ leaching, solution mining, coal gasification, borehole mining – to name a few. Today, these technologies are used at the commercial level and are well presented in scientific conferences, publications, patents, internet blogs and similar venues.

Meanwhile, the widespread geography of mining companies, schools and individuals interpreting these technologies, has caused some serious clutter in terminology. For example, Borehole Mining (BHM) has various "additional" names such as Borehole Hydraulic Coal Mining System (BHCMS), Hydraulic Underground Mining of Oil Sand (HUMOS), Hydraulic Borehole Mining (HBHM), Underground Hydraulic Mining (UHM), Surface Access Borehole Resource Extraction (SABRE) and so on. In contrast, there are attempts to call "any process in which minerals are fluidized in place by some means and removed via borehole" as Borehole Mining. Such a muddle does not help young scholars and engineers to grasp the situation and familiarize themselves with the mining world. This article is an attempt to clarify and organize mining terminology based on existing and historically prevalent terms, meanings and definitions.

INTRODUCTION

How many methods are forming the modern mining arsenal? While the question seems to be a simple one, the answer is actually pretty complicated. Coming up with the exact number is practically impossible due to the variety of these methods variations, and combinations. Even within a simple category, such as surface mining, different authors oftentimes include some “alien” technologies (such as in-situ leaching) which do not perfectly fit there, to say the least.

Nevertheless, it is generally accepted that there are two conventional categories: Surface and Underground mining [1] (Fig 1).

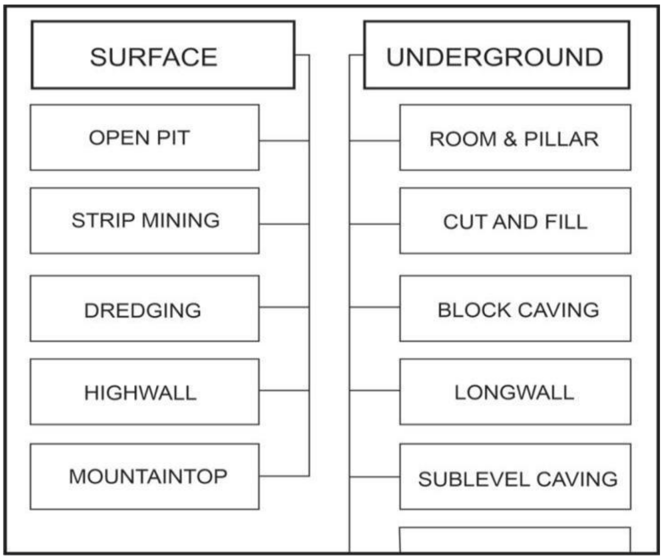

Fig 1. Conventional mining methods

Note: some sources allocate a few more surface mining methods, such as Quarrying, Placer Mining, etc. which at the end of the day are variations of Open Pit or Strip Mining.

While there are only a few generally accepted surface mining methods (Fig 1), the list of underground methods is at least twice as long. The symmetry in Fig 1 is to equalize the importance of both mining categories, which are long-established and do not require additional adjustment and re-ranking.

But what about mining (and look-like mining) methods (Fig 2) which do not fall into the Conventional category?

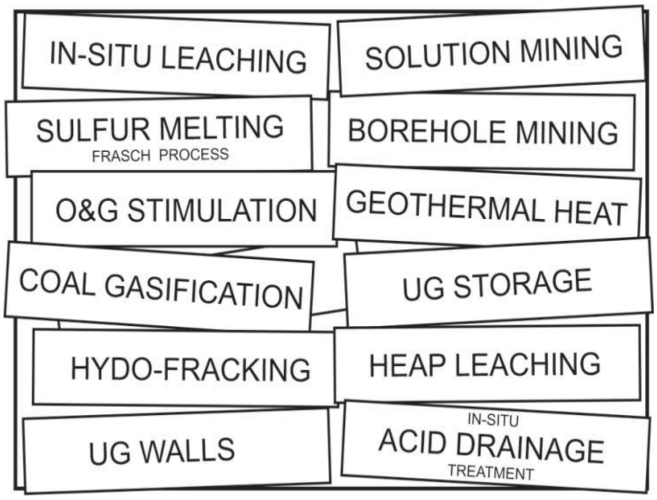

Fig 2. Unconventional mining, stimulation and construction methods

Where do they belong? And, do they deserve a more specific title than Unconventional?

Also, what about those look-like mining operations, such as underground storage construction in salt domes, oil & gas stimulation, construction of underground walls, abandoned mines in-situ acid drainage treatment [2] and several more? Which category do they fit into?

GEOTECHNOLOGY

Whether it is an orebody, leaching heap, construction zone or stimulation interval, all the methods in Fig 2 are Geotechnological. *Geotechnology* (GT) *is a set of engineering sciences and mining techniques concerned with extraction of Earth's natural resources based on their in-situ conversion into a liquid or gaseous form* [3]. Among these GT techniques, there are stand-alone methods called Mineless. Their distinguishing feature is that they are operated through boreholes drilled from the earth surface, mine floor, underground working or ocean platform. These methods are briefly described below.

SOLUTION MINING (SM) is applied to recovery of soluble minerals, such as salt. It requires either a single or multiple boreholes and consists of injecting fresh water down into the salt dome and extracting saturated brine.

IN-SITU LEACHING (ISL) is applied to the extraction of metals. A reagent is pumped into the formation through injection holes. As it travels through the ore to the extraction holes, it dissolves metal and the created pregnant solution is pumped to the surface.

Fig 3. Geotechnology VS. Conventional Mining

SULFUR MELTING MINING (SMM) (Frasch process) includes pumping super-hot water into the sulfur layer(s), melting the sulfur and pumping it back up to the surface in a molted form.

UNDERGROUND COAL GASIFICATION (UCG) consists of pumping of Oxygen (air) into the coal layer(s) followed by its ignition. Produced syngas is pumped to the surface and used for generating of energy.

BOREHOLE MINING (BHM) is applied to the extraction of soft, unconsolidated ores (iron, coal, gold, uranium, rare earths, other). It is based on in-situ water jetting of ores. Produced slurry is simultaneously pumped to the surface.

HEAVY OIL STIMULATION (HOS), similarly to Frasch, is based on injection of super-hot steam into the oil formation through borehole(s), heating up the surrounding strata and extraction of "liquefied" oil through the same or adjacent holes.

GEOTHERMAL ENERGY (GTE) requires injection and production holes and includes pumping of water from the surface through the hot Earth crust, heat exchange and delivery of hot water to the surface.

Additionally, all the construction, stimulation, in-situ acid drainage treatment and other methods conducted through boreholes also belong to the GT Mineless category.

Comparing the diameter of a GT borehole (usually less than 20 inches) to the size of an open pit (Fig 3) or underground mine, some resear chers [4] suggest the term *Non-intrusive*, which in this case is a synonym to the term Mineless.

Positioned on the rim of the open pit (Fig 3), a BHM rig conducting gold mining is a great illustration [5] of the major differences between Conventional Mining and Geotechnology. Yes, it will require numerous of boreholes to develop the entire ore body, but the Earth will be left mostly undisturbed.

Conventional and most common mineless (non-intrusive) geotechnological mining methods as well as their major action type and typical final product are presented in Table 1.

Table 1. Conventional and mineless (non-intrusive) geotechnological methods

METHOD	CONVENTIONAL		GEOTECHNOLOGICAL (MINELESS / NON-INTRUSIVE)							
TECHNOLOGY	SURFACE	UGM	ISL		SM	BHM	SMM	HOS	UCG	GTE
ACTION	Physical		Chemical	Bacterial	Chemical	Physical	Thermal		Combustion	Heat x-change
FINAL PRODUCT	Ore		Metal		Salt	Ore	Sulfur	Oil	Syngas	Heat

Most of the GT methods are uniquely designed for mining a specific product. Furthermore, each can be additionally adjusted depending on the product properties, mining depth, production interval thickness, geological, hydro-geological and other conditions. Selecting an appropriate geotechnological method for a specific project is a pretty straight-forward task. However, to set up the most effective technological mining parameters requires sufficient *geotechnical* studies [6], including geology, rock mechanics, hydro-geology, lithology, lab-tests, computer simulations, etc. The term “Geotechnical” is well adopted industry-wide and is properly used.

To better visualize the differences between the conventional and geotechnological methods and compare them back-to-back including their major steps, a comparison chart is presented in Fig 4.

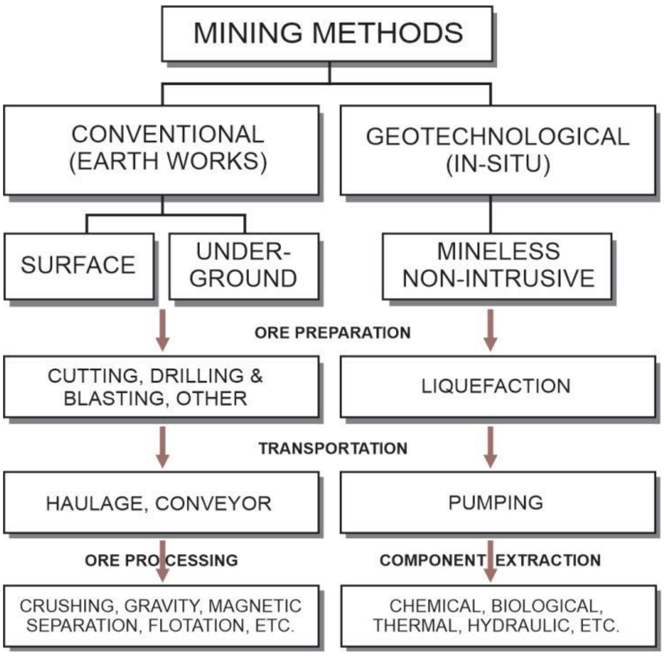

Fig 4. Conventional and GT mineless methods comparison chart.

"Mineless/Non-intrusive" in Fig 4 means there are no activities typical for conventional mining operations, such as overburden removal, ore transportation, etc. It also means that mineless technologies are remote-operated and controlled through boreholes which provide immediate access to the orebody. These technologies eliminate the need for the presence of personnel underground. They are controlled by computer operators from the ease of climate-controlled stations, including those over the Internet. Finally, they shrink staff requirements significantly. *This is mining without miners.*

Remote control of operations also allows mining in submerged, hazardous, unstable, caving-in conditions, and broadens the mining application area to offshore, desert and polar zones. Because these methods are non-intrusive, they are the most environmentally friendly, rapidly implemented and cost effective. These attributes serve to minimize the atmospheric pollution and environmental impact. All these advantages finally make possible extraction of many world mineral reserves previously deemed uneconomical.

MISCELLANEOUS SECTOR

Finally, what about those GT methods which cannot be qualified as Mineless, such as heap leaching? This method matches geotechnological category requirements as it is based on the in-situ (in this case in a heap) conversion of a target-element (metal) to a liquid (solution). However, to form a heap, conventional mining is required. Thus, these technologies fall into a stand-alone Miscellaneous category, meaning that they are a combination of conventional and geotechno-logical methods.

In other words, any mining, environmental, construction or stimulation method which does not qualify as Conventional or GT-mineless falls into the Miscellaneous sector. A good example here is the extraction of valuable minerals and elements from sea-water. According to [7], there are over 40 such elements worth of of Trillions Dollars in the World Ocean waiting for extraction.

THE MINING WHEEL

As set forth above, the modern mining industry consists of four technological sectors: 1 - surface, 2 - underground, 3 - geotechnological and 4 - miscellaneous. These four sectors form an interconnected, circular diagram - The Mining Wheel presented in Fig 5.

The Wheel consists of three identical sectors: Surface, Underground and Geotechnology. In Fig 5, these sectors do not necessarily include all known mining methods but rather designate their existence and equal importance.

The fourth, Miscellaneous sector is split in two identical sub-sectors, M1 and M2 located each along the borders between Geotechnology and Conventional sectors.

Again, using heap leaching as an example, if the ore has been extracted by a surface method, it fits in the left Miscellaneous sub-sector M1, adjacent to the Surface sector. If it was extracted by an underground technique, it falls in the right subsector M2.

Now, looking “thru” the Wheel, where does underwater mining fall in? There are two strong factors which suggest inclusion of this technology in the Surface mining category: (1) the ocean floor is the surface of Earth and (2) whether it is seafloor dredging, milling or scooping, these are typical surface mining operations.

Thus, the Surface mining sector as well as Underground and Geotechnological are presented in the Wheel by six technologies each.

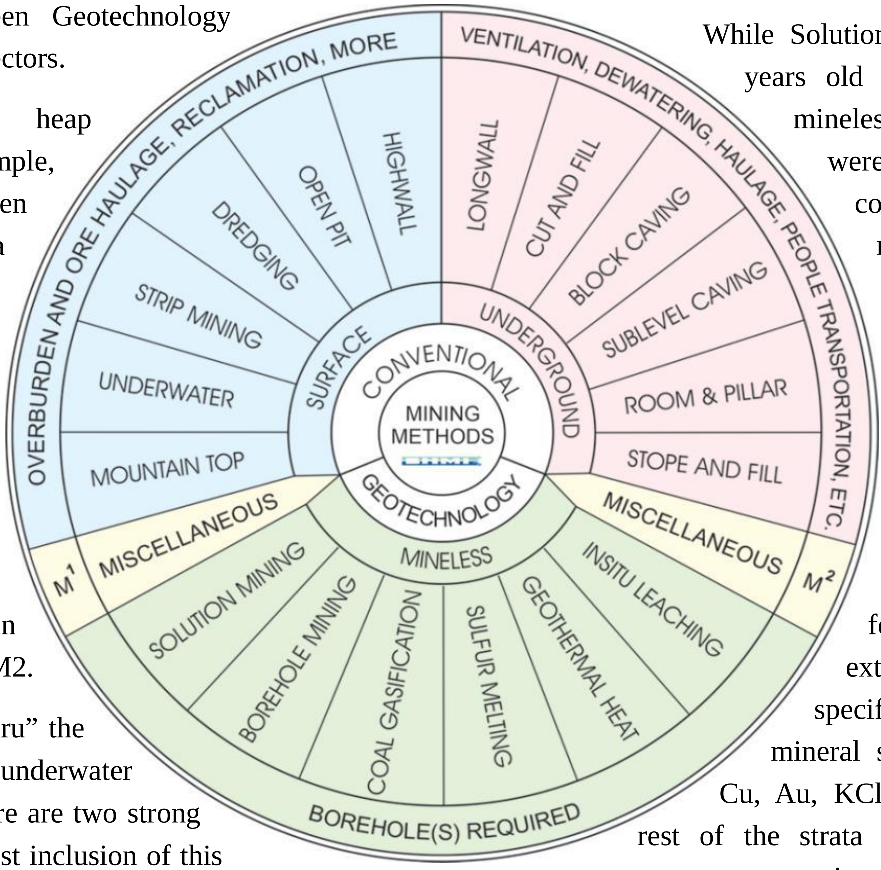

Fig 5. The Mining Wheel

The Wheel represents the entire mining industry, covering all existing mining methods and categories. But, it is not once-and-for-all dogma. It remains a living diagram. As all mining and engineering sciences continue to evolve, most likely new mining methods will soon become available and, as new spokes, they will find their place on the Wheel, steering the industry to better serve our society and preserve our planet.

A good example of such a future spoke is space mining, Fig 6. Whether it will fall into the existing categories or create a new one, it will make the Wheel more complete, interactive and versatile [10].

CAREFULLY WITH TERMINOLOGY

While Solution Mining is 2250 years old [8], most of the mineless GT methods were developed and commercialized in mid-20th Century. Strictly speaking, except borehole mining, all of them are *extraction* rather than mining technologies as they are designed for a pinpoint extraction of a specific element or mineral such as NaCl, U, Cu, Au, KCl, etc. leaving the rest of the strata in-place. For the newest generations of researchers, it may seem somewhat advantageous to try to correct or adjust those terms which may appear inaccurate or even “invent” new ones. However, before doing so and adding new terms to the Wheel, it is important to treat carefully those historical, well established methods and their prevalent, industry-widely adopted terminology. This will help to avoid confusion, chaos and clutter in mining terminology.

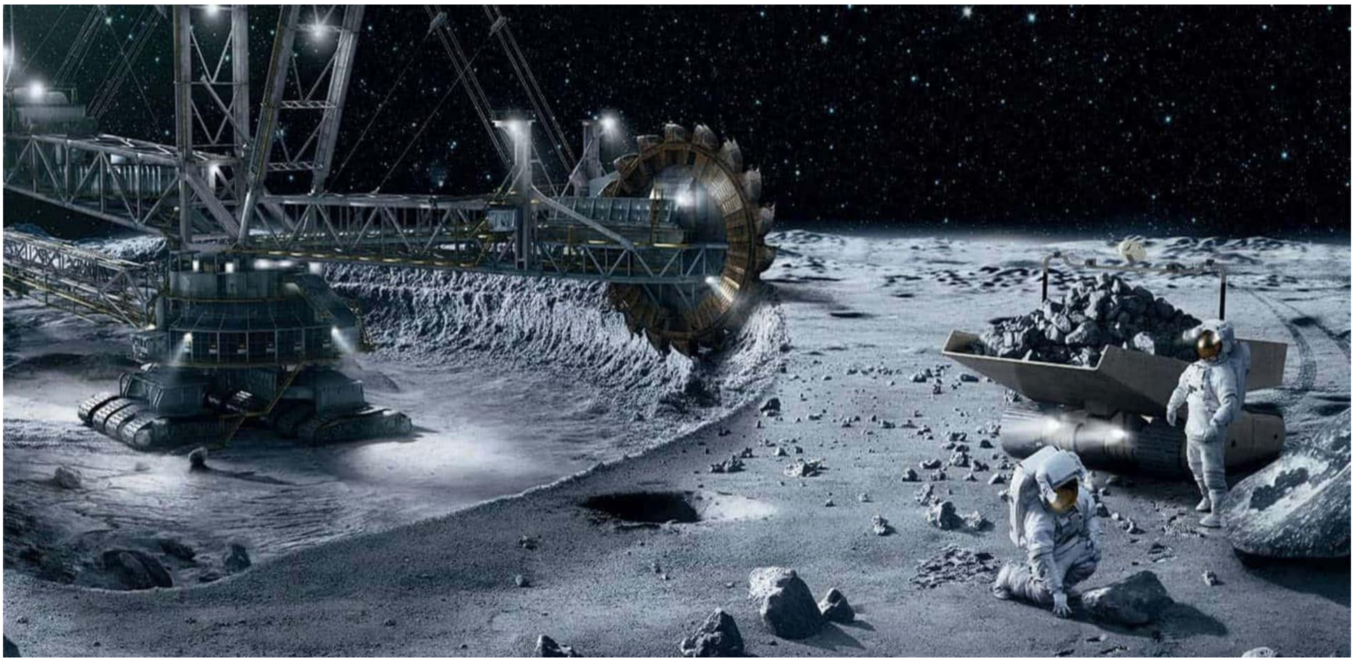

Fig 6. A bucket-wheel developing space resources [11]

CONCLUSION

The 21st Century is marching-on, and so too are the mining industry, science and engineering disciplines. Experts recently observed an upsurge in the patenting of new mining techniques [9] which would make it safe to predict significant progress in the area of mining technologies development within the next few decades. And proper use of terminology will help everyone to better understand the basics of the industry, to move it forward and to secure a reliable transition from its past to the future.

ACKNOWLEDGEMENT

The author expresses thanks to the scientists and engineers who he was lucky to meet and work with developing borehole mining technology since the 1970s.

The author expresses special thanks to his long-time mentors Dr. Nikolai I. Babichev and Dr. Nikolai G. Malukhin, Moscow Geo-Prospecting Institute, for imparting theoretical and practical knowledge in and interest to the mining sciences and Mr. Thomas C. Pool, International Nuclear, Inc. for important input, information and advice.

References

1. SME Mining Engineering Handbook, 2nd edition, *Society for Mining, Metallurgy and Exploration, Inc.*, Littleton, CO, 1992

2. G. Abramov "Borehole Mining: Environmentally Friendly, Underused". *Mining Engineering Magazine*, 04/2001

3. G. Abramov "Mining Terminology Disarray" *Mining Engineering Magazine, Web Exclusive*, 08/2019

4. V. Arens “About the Term “Geotechnology”, *Russian Academy of Natural Sciences*, Mining Bulletin, 1998

5. The winner of the 2nd Prize of the Photo Contest by *Mining Engineering Magazine, 2013*. Courtesy by Borehole Mining International, Inc.

6. *The Collins English Dictionary, Harper Collins*, Glasgow, UK

7. Keith Campbell "Treasure Chest" *Mining Weekly*, 04/01/2016

8. Mark Kurlansky, “Salt: A World History”, *Random House Canada, Ltd.*, Toronto, 2002

9. Alica Daly, Giulia Valacchi, Julio Raffo “Mining patent data: Measuring innovation in the mining industry with patents”. *World Intellectual Property Organization*. Economic Research Working Paper No. 56, 05/2019

10. A three-dimensional Mining Wheel can be viewed at *boreholemining.com*

11. Excavator in Space - Unearthing the Future of Mining, *wallpapers.com*